MICROFLORA OF WHEAT AND WHEAT FLOUR FROM SIX AREAS OF THE UNITED STATES

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ABSTRACT

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Bacterial counts in 54 wheat samples varying from 870 to 3,100,000 per gram generally were higher than in corresponding flour samples. Of 54 flour samples, bacterial counts per gram were less than 5,000 in 32 samples and less than 10,000 in 43. In 32 patent flours, bacterial counts per gram were less than 5,000 in 25 samples and less than 10,000 in 30. In most samples, fungal

and actinomycete counts were inconsistent, but were lower than bacterial counts. Though psychrotrophic bacteria ranged from 0 to 106, counts of catalase-negative, fecal streptococci, aerobic thermophilic spore-forming, and flat sour bacteria were low when detected. Correlations are not evident among microbial counts in wheat and flour samples.

Wheat flour is used in canned foods, especially baby foods, and is a major ingredient in many nonsterile refrigerated and frozen convenience foods. Reported bacterial counts in wheat and flour vary considerably, ranging from a few hundred per gram to millions (1). Doty (2) has recommended bacterial limits in flour depending on its intended use, ie, 5,000 bacteria/g in TV dinners and meat pies, 10,000/g in fruit pies, and 15,000/g in canned biscuits. Some processors specify flour with less than 5,000 bacteria/g (3). The question is whether bacterial counts are relevant to flour quality.

Many other questions arise: Are fungal and actinomycete counts relative to bacterial counts in wheat and flour samples? What is the relationship between the different microbial counts in wheat and the flour milled from it? Does the microflora of flour reflect that of the grain before milling? Are these microorganisms responsible for spoilage of grain, its products, and byproducts? Do they represent health hazards? Within a region, are the microflora of the products similar?

For insight into these problems and to establish the microflora of domestic wheats and commercial flours, a survey was made of various mills throughout the United States in cooperation with the Millers' National Federation. Several facets of the survey have been reported elsewhere (3-5).

MATERIALS AND METHODS

Sampling

Representative flour mills in Kansas-Nebraska, the Pacific Northwest, Michigan-Indiana, Montana-North Dakota, Texas-Oklahoma, and the Southeast collected and sent 54 samples of locally grown wheat and its flours to our laboratory. At each mill, sampling was conducted only one day during the fall and winter. Only two Pacific Northwest mills processed locally grown wheat. Samples were typical wheats and flours having no known spoilage problems.

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TABLE I Counts of Microorganisms in Wheat and Flour (Per Gram)

Pacific					lebraska	Kansas-N		
	teria	Bac	mycetes	Actino	ngi	Fui	eria ²	Bacte
	F	W	F	W	F	W	F°	\mathbf{W}_{\perp}^{b}
an 5,000	Less th							
•	0.2	5.5	60	40	270	90	0.8^{d}	160
			80	85	1,000	550	1.3	590
				65		15		3.7°
			65		85		3.0	
				35		220		35
			25	140	2,000	330	3.2	66
			155	125	130	390	3.3	93
			10 90	55	[600]	75	3.6	38
				100	90	330	4.6	97
			1,000	295	8,000	250	4.8	110
			170	20	310	170	4.8	140
to 10,000					200			
	8.6	3.6	60	100	300	1,300	6.6	650

More than 10,000

		Me	ontana-No	rth Dakot	а		Texas-
						7.8 4.3 1.0 0.87 9.1 0.89 33 44 39	Less than 5,000 0.46 ^d 30 0.7 150 1.0 270 1.3 110 1.41 130 12.3 50 3.8 35 4.7 350 4.9 9,500
1,300 490 570 1,500	5.0 5.8 6.8	10,900 2,200 2,700 32,000	210 2,200 230 360	35 40 10 10	60 [15] [0] 70		5,000 to 10,000
780 3,100 3,000 2,000 300 1,600 1,300	10 [25] 39 41 45 190	1,900 86,000 750 1,600 650 3,100 3,800	200 [1,500] 900 300 1,100 700 260	45 15 10 15 0 20 20	25 5 45 0 40 15 5	122	More than 10,000 120 50

^aBacteria/gram in thousands. ^bW = wheat counts.

F = flour counts.

^d□= Patent flours.

^eTwo wheats sent with one flour.

Two flours sent with one wheat.

Northw	est					Michigan			
Fun	gi	Actinom	ycetes	Bact	eria	Fu	ngi	Actino	mycetes
W	F	W	F	W	F	W	F	W	F
bacteria 110	a/gram flo 195	our 0	10	45 280 13	0.45 0.64 0.85	470 3,500 135	330 400 110	35 65 170	85 600
				91 16	1.3 1.5 3.3 ^t	190 230	200 230 1,500	110 5 90	45 0 70
				240 21	16 3.9	2,800 75	2,800 240	35	150 75
250	/gram flo 2,500 a/gram flo	130	10	91 68 54	5.3 5.4 6.6	2,100 470 1,000	7,500 900 170	1,100 15 195	5,300 100 265
				8.2 16	12 12	470 17,000	900 8,200	60 155	55 230
Oklahoi	ma					Southeas	stern State	÷5	
bacteria 1.200 1.50 1.300 800 190 270 1.500 1.000 9,500	90 25 100 40 75 95 15 430 75	50 10 110 80 130 550 5 83	-	61 61 97 69 97 57	0.13 0.96 1.2 1.4 4.1 4.4	280 50 235 265 750 550	190 150 130 110 490 1,400	340 5 65 45 75 80	[2 [3 [1] [1]
bacteria	/gram flo	ur		69 67	5.2 [5.5]	1,050 2,300	750 290	360 90	4 [14

bacteria/gram flour
380 460 [1,900]

Bacteriologic Examination

Graves and Hesseltine (4) described the method for enumerating aerobic fungi and Graves et al (3) for aerobic bacterial and actinomycete populations. Samples were either examined the day received or stored at 5°C until analyzed.

RESULTS

Bacterial, fungal, and actinomycete counts are the average count from duplicate plates. Samples are arranged according to increasing bacterial counts in the flour (Table I). Microbial counts of the wheat and corresponding flour sample may be compared. For example, the last count in the Kansas-Nebraska column represents a wheat sample having 650,000 bacteria, 1,300 fungi, and 100

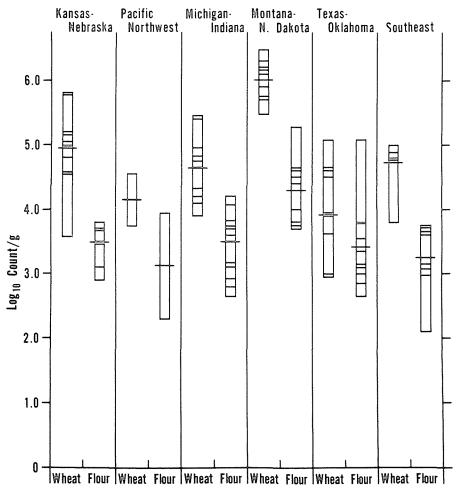


Fig. 1. Bacterial counts in wheat and flour samples from six areas of the United States.

actinomycetes per gram and its flour having 6,600 bacteria, 300 fungi, and 60 actinomycetes per gram.

Visual comparisons of counts in wheat and flour are shown in Fig. 1–3. The vertical bars represent the range of counts and the small horizontal lines are counts for each sample. The geometric means are depicted by longer horizontal lines.

Although bacterial counts in wheat samples ranged from 870 to 3,100,000 per gram, the geometric mean was 71,000 per gram. The lower geometric mean of flour samples (3,900 per gram) reflects generally lower bacterial counts, ranging from 130 to 190,000 per gram. Montana-North Dakota samples have higher counts, and six Montana-North Dakota flour counts exceeded 15,000 per gram (Fig. 1). Of 54 flour samples, however, the total bacterial count was less than 10,000 per gram in 43 samples analyzed (including 30 patent flours) and less than 5,000 in 32. Most bacterial counts were greater than fungal counts.

Fungal counts ranged from 15 to 86,000 per gram of wheat and from 85 to 9,500 per gram of flour; the geometric means were 520 and 540 per gram,

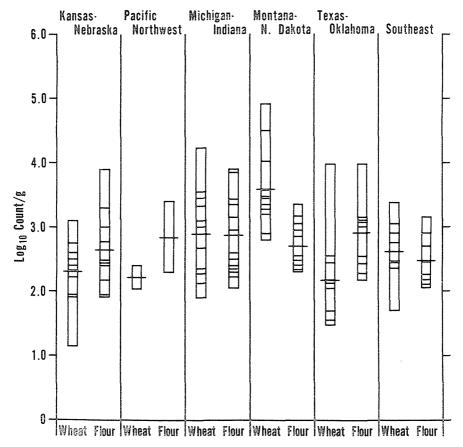


Fig. 2. Fungal counts in wheat and flour samples from six areas of the United States.

respectively. Counts exceeding 1,000 were found in 18 wheat and 17 flour samples, including 9 patent flours. More wheat samples from Montana-North Dakota and Michigan-Indiana and more flour samples from Texas-Oklahoma and Michigan-Indiana revealed higher counts than from other areas (Fig. 2). Though some wheat and flour samples from all areas had high fungal counts, no trend was noted; the same was true of actinomycete counts.

Most actinomycete numbers were less than fungi, ranging to 1,100 per gram of wheat and to 5,300 per gram of flour; the geometric means were 49 and 45 per gram, respectively. Though actinomycetes were not detected in several samples, counts were less than 100 per gram in 36 wheat and 35 flour samples and exceeded 100 per gram in 32 samples, including 10 patent flours (Fig. 3). In most patent flours, however, the actinomycete count was low (Table I).

In addition, samples were examined for specific bacteria (Table II). Psychrotrophic bacteria were detected in most samples. Catalase-negative bacteria were found in 19 samples and fecal streptococci in 24; 78 samples contained aerobic thermophilic spore-forming bacteria, and 57 had flat sour bacteria. Most counts were 10 or less, but counts of psychrotrophic bacteria ranged from 0 to 3,000,000, and catalase-negative bacteria, up to 2,500.

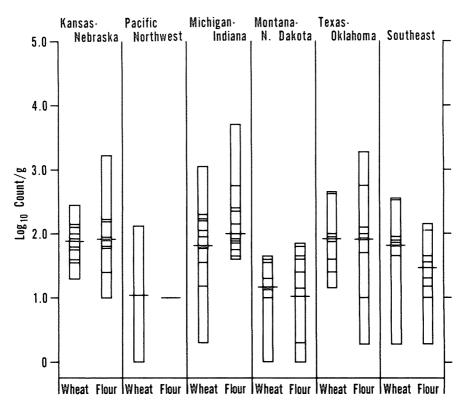


Fig. 3. Actinomycete counts in wheat and flour samples from six areas of the United States.

DISCUSSION

The microflora of the wheat and flour samples examined was heterogenous. Bacteria, fungi, and actinomycetes were found in most samples. Organisms common to both wheat and flour, such as psychrotrophic bacteria, fecal streptococci, catalase-negative bacteria, aerobic thermophilic spore-forming bacteria, flat sour bacteria, Aureobasidium pullulans (5), and Streptomyces albus (3), survived the milling processes.

During milling, however, up to 95% of the microbial population may be removed with the feed fractions (6). When counts are compared (Table I) in flour and in wheat from which the flour was milled, the bacterial population in most flours was about one-tenth that in wheat. This indicates that modern flour milling operations are efficient in reducing the number of bacteria.

Even though bacterial numbers were less in flour than in wheat, the fungal and actinomycete counts in flour were not always lower. Larger numbers in flour could be due to conditions favoring growth of microorganisms originally present in the grain, to dispersion of spores during sample handling, or to contaminants in the mill (7). Similar counts in wheat and flour, but a different flora, suggest that mill contaminants have replaced organisms originally present. Similar counts (due to replacement) and lower counts might be the result of selective removal of organisms during milling, eg, a yeast (*Cryptococcus albidus*) was common among wheat samples but was not detected in any flour samples examined (5). Fungal and actinomycete counts are unrelated between wheat and flour samples.

If Doty's (2) suggestions of bacterial counts in flour are considered, 32 samples had less than 5,000 per gram, 43 had less than 10,000 per gram, but 7 had more than 15,000 per gram. Of 32 patent flours, bacterial counts were less than 10,000 per gram in 30 samples, but fungal and actinomycete counts were inconsistent. Bacterial counts and fungal or actinomycete counts however, are unrelated in flour samples (Table I). For example, a flour sample from Texas-Oklahoma with less than 5,000 bacteria/g contained the highest fungal count (9,500 per gram), and the highest actinomycete count of 5,300 per gram in a Michigan-Indiana sample had 5,300 bacteria and 7,500 fungal propagules/g.

Quality of flour based on total bacterial numbers supplies no information about bacterial flora. Certain bacteria might indicate possible health hazards and others might cause spoilage of the product. Detection of these bacteria (Table II) might be a warning to various industries, but established tolerances were exceeded in only a few samples. Aerobic thermophilic spore-forming bacteria, which may cause spoilage in canned foods, were present in 78 wheat and flour samples, but the National Canners Association's recommendations (8) were exceeded in only 5 flour samples. Flat sour bacteria are a group of thermophilic spore-forming bacteria that cause food to turn sour; they were detected in 57 wheat and flour samples, but counts exceeded the National Canners Association's recommendations (8) in only 2 Kansas-Nebraska flour samples.

Though fecal streptococci were detected in 24 samples, the 20 per gram tolerance (8) was exceeded in only 2 flour samples. Lactic acid bacteria have been implicated in spoilage of refrigerated canned biscuits, but 100 per gram are tolerated by industry (9). Flour may be the source of such contamination. Lactic acid bacteria were detected in 13 flour samples, and 6 exceeded the tolerance.

TABLE II
Wheat and Flour Samples Tabulated by Area and Count Range of Specific Bacteria

							Cor	ınt Rar	ige Per Gram
	Number of_			Psyc	hrotroj	phic Ba	cteria		
Area and Sample	Samples	0	<10	10 ¹	10 ²	10 ³	104	10 ⁵	10 ⁶
Kansas-Nebraska									
Wheat	11	2					6	3	
Flour	10	i		1	6	2			
Pacific Northwest									
Wheat	2			1			1		
Flour	2 2	1				I	-		
Michigan-Indiana									
Wheat	12					3	7	2	
Flour	13				6	3 5	7 2		
Montana-N. Dakota									
Wheat	11						1	6	4
Flour	11					7	3	1	
Texas-Oklahoma									
Wheat	10			1	3	2	4		
Flour	10	1			3 I	2	4 5		
Southeast					_		-		
Wheat	8			1	5	2			
Flour	8 8			1	5 5	2 2			
Total wheat	54	2		3	8	7	19	11	4
Total flour	54	2 3		2	18	20	10	1	0
Total samples	108	5		5	26	27	29	12	4

Organisms important to the chilled and frozen food industries are able to withstand cold temperatures. These psychrotrophic bacteria were detected in most wheat and flour samples, and counts exceeded 100 per gram in 31 flour and 41 wheat samples.

On a geographic basis, regional differences may be noted. Wheat and flour samples from Montana-North Dakota had higher, and Texas-Oklahoma lower, bacterial counts than those from other areas. Bacteria require moisture for growth and are able to tolerate cool temperatures, but only spore-forming bacteria can withstand prolonged arid conditions combined with heat. Flours containing higher psychrotrophic counts came from Michigan-Indiana and Montana-North Dakota, while more aerobic thermophilic spore-forming and flat sour bacteria were detected in Kansas-Nebraska flours.

Elevated counts of fungi and actinomycetes do not correlate with high bacterial counts. High fungal counts in wheat and flour samples came from all areas, especially nine Montana-North Dakota wheat, five Texas-Oklahoma flour, and three Montana-North Dakota flour samples. Little relationship exists between elevated fungal counts and other high counts. High actinomycete counts were noted in five wheat samples from both Michigan-Indiana and Kansas-Nebraska, and in five Texas-Oklahoma, six Michigan-Indiana, three Kansas-Nebraska, and two Southeastern flour samples.

Since correlations are not evident among individual samples, an independent phenomenon is suggested, ie, samples with high bacterial counts may not always

Catalase-Negative Bacteria					Fecal Streptococci				Aerobic Spore-Forming Bacteria				Flat Sour Bacteria		
0 <10	10 ¹	10 ²	10 ³	0	<10	10 ¹	10 ²	0	<10	10 ¹	10 ²	0	<10	10 ⁱ	
10 6	4		1	8 9	2	1		3	8 3	2	2	5 5	6 3	2	
1	I	1		2 2				1 2	I			2 2			
11 13			l	8 11	3	1		4 1	7 I I	1		5 4	6 9	1	
11 6	1	3	l	8 8	2 3	I		4 4	7 7			7 4	4 7		
9 9	1	I		8 6	2 3	1		3	7 9			5 2	5 8		
6 I 6 I		1		6 8	I	1		3 1	5 7			5 5	3 3		
48 1 41 1 89 2	1 6 7	2 5 7	2 1 3	40 44 84	10 8 18	4 2 6	0 0 0	18 12 30	35 37 72	1 3 4	0 2 2	29 22 51	24 30 54	1 2 3	

have high numbers of fungi or actinomycetes nor will high counts in wheat indicate high flour counts. Generally, however, bacteria are the predominant organisms, followed by fungi and actinomycetes in both wheat and flour.

This survey illustrates the heterogeneity of the microflora and the complexity of microbial problems associated with wheat and flour milled from it.

Acknowledgment

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